Nuclear Magnetic Resonance Studies of Iron Pnictides BaFe2(As[1-x]Px)2(Digest_要約)

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A brief summary of "Nuclear Magnetic Resonance Studies of Iron Pnictide $BaFe_2(As_{1-x}P_x)_2$ "

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In this thesis, we demonstrate our nuclear magnetic resonance (NMR) studies of iron-based superconductor (iron pnictide) $BaFe_2(As_{1-x}P_x)_2$, which have clarified the following anomalous properties: quantum criticality, spatial coexistence of magnetism and superconductivity, and orbital nematicity.

The discovery in 2008 of iron pnictide with a relatively high T_c brought a breakthrough in developing a totally new group of unconventional superconductors with high-T_c. Subsequent researches have pushed T_c to its current record 56 K, which is the highest other than the high-T_c cuprates. The researcher's interests also go to their rich physics. Variety of crystal structures, electronic phase diagrams, and superconducting gap structures are found in the iron pnictides. As the variety increases, the unified understanding of the physics in the iron-based superconductors becomes more and more challenging. However, one can find some characteristics of superconductivity common to almost all of the pnictides as well as high-T_c cuprates and heavy fermions. In many cases, the superconducting phases in these materials appear next to the magnetic ordered phase in their electronic phase diagrams. This commonality implies that there is some relationship between magnetism and superconductivity. Early studies of the heavy fermions and the cuprates have indeed established the importance of magnetism for their superconductivity. The relationship between magnetism and superconductivity in the pnictides is a subject of great interest to the researchers.

NMR is such a powerful technique that allows to investigate magnetic and electronic properties of materials from microscopic point of view. This local probe technique takes advantage of the hyperfine coupling mechanism of the nuclear spins to the electrons (quasiparticles) in the normal (superconducting) state. Since NMR is sensitive not only to static magnetism but also to dynamic magnetic fluctuations (low-energy excitations) and electric information around the nuclear site, NMR experiments can provide many useful informations in any phases.

Among various kinds of iron pnictides, $BaFe_2(As_{1-x}P_x)_2$ has become one of the most well-studied material since this system allows us to obtain very clean single crystalline samples. $BaFe_2(As_{1-x}P_x)_2$ is also suitable for NMR experiments because it contains two types of atoms at the same site: ^{31}P and ^{75}As. While ^{31}P can probe only magnetic interaction, ^{75}As can probe both magnetic and electric-quadrupole interactions between nuclei and electrons. In this work, we focus on P-underdoped $BaFe_2(As_{1-x}P_x)_2$ showing antiferromagnetic orderings, which are less studied compared to the optimally-doped one. Since the superconductivity appears around the point where antiferromagnetism is suppressed, it is quite important to understand magnetism as the background of the unconventional superconductivity.

This thesis is organized as follows: We will first provide the necessary background knowledge of the iron-based superconductors and then will review the research material $BaFe_2(As_{1-x}P_x)_2$ in Chapter 1. Chapter 2 will serve as the introduction to our experimental technique Nuclear Magnetic Resonance (NMR). Chapter 3 will deal with experimental details including NMR measurement setup, properties of the samples, and experimental conditions for NMR measurements. In Chapter 4, a short review of the previous NMR studies of $BaFe_2(As_{1-x}P_x)_2$ will be given. Chapter 5, 6 and 7 are the main contents of the thesis. In Chapter 5, we will discuss magnetic quantum criticality through the results of ^{31}P-NMR measurement for $BaFe_2(As_{1-x}P_x)_2$ polycrystalline samples which show antiferromagnetic (AFM) transition. The averaged magnetic ordered moment $<m>$ at the zero-temperature limit, which is estimated from the ^{31}P-NMR spectrum shows a continuous decrease toward $x \sim 0.35$ with increasing P concentration x, verifying that a second-order quantum phase transition occurs at $x \sim 0.35$. In Chapter 6, we will present ^{31}P-NMR measurement for coexisting phase of AFM and superconductivity. The nuclear spin-lattice relaxation rate measurement of ^{31}P at the magnetically ordered site revealed that SC transitions occur in magnetic ordered region of the sample. This is the direct evidence of spatial coexistence of superconductivity and antiferromagnetism in the microscopic scale. Finally, in Chapter 7, we will focus on ^{75}As-NMR study of a single crystalline sample of $BaFe_2(As_{1-x}P_x)_2$. By measuring in-plane field orientation dependence of ^{75}As-NMR spectrum of the single crystal above T_S, the presence of in-plane anisotropy in electric field gradient arising from population imbalance between As-$4p_x$ and $4p_y$ orbitals is clarified. Then, we will summarize our experimental results and make conclusions in Chapter 8.